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ARCHITECTURE OF DIGITAL CONTROLLERS FOR POWER STATIONS

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1. FOREWORD

Digitalization of controllers for power stations has increased the number of application power stations and broadened the range of application of the control functions ever since the application of the sequencer controller with only control circuits consisting of magnetic relays in the 1960s.

The programmable controller (PC) has been made more reliable, its processing speed has been increased, and it has been given more advanced functions through the development of technology.

In the 1970s, automatic power factor control, dam water level, and other control functions that needed a scan time of about 100 msec were digitalized by PC. In the 1980s, automatic voltage regulator (AVR), governor (GOV), and other control functions that needed a scan time of about 10 msec were realized and digitalized on a PC.

The functions and performance demanded of various digital controllers for power stations and the present state of the architecture which realizes them are introduced.

2. OUTLINE OF CONTROL SYSTEM FOR POWER STATION

The construction and control functions of a control system differ with the form of the power station, that is, whether it is thermal or hydraulic and electric company or private and with the generator capacity, etc.

The relationship between power station size and digital control system equipping conditions is shown in *Fig. 1.*

The control system is outlined below.

2.1 Large power station control system

2.1.1 High reliability system

When a thermal power station and large capacity power station is stopped by a fault, its social effect is large. Therefore, it is important that the fault resistance of the controller itself, of course, be high and that redundancy as a system be possible.

Generally, the dual or duplex system is popular as

Fig. 1 Power station size and controller functions

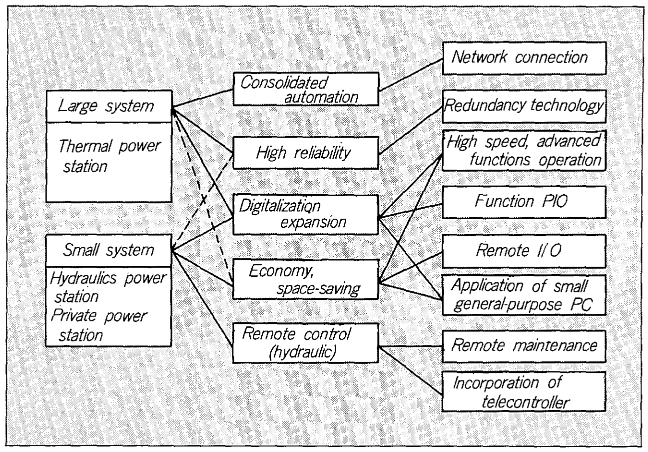
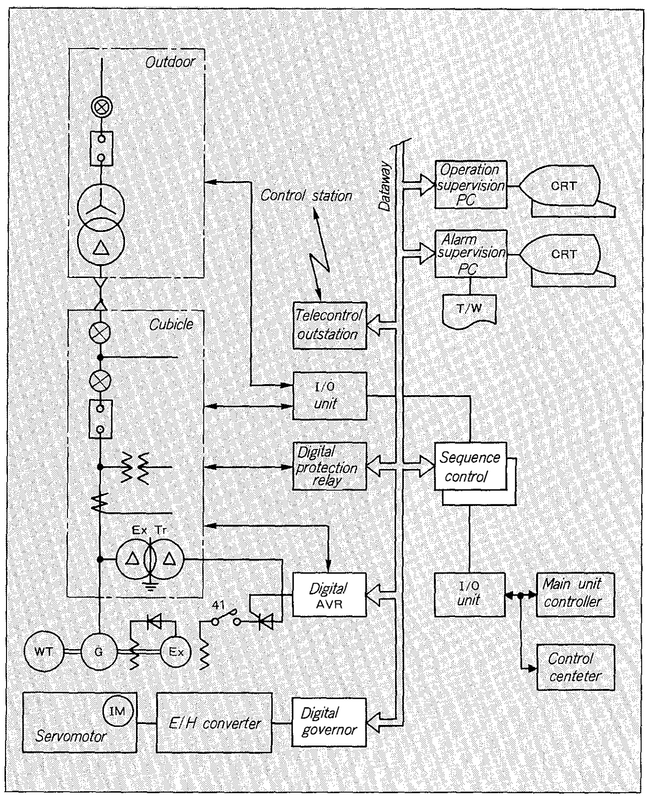


Fig. 2 Hydraulic power station configuration example



a redundancy system, but for large thermal power stations, there are many examples which use a triplex system to secure greater reliability.

2.1.2 Consolidated automated control system

For large system, a controller is installed for each control objective from the standpoints of absorption of large capacity control functions, distribution of danger, etc. and the control system is assembled by connecting each device and the supervisory and control system by a dataway.

Figure 2 shows an example of a hydraulic power station. The PC for the main unit is duplexed and a individual PC is provided for AVR use and governor use.

For a large thermal power plant, boiler and burner control are also added. Moreover, since a redundancy system is required, 10 or more PCs are provided for one power station.

2.2 Medium and small power station control system

2.2.1 System that pursues economy and space-saving

It is only natural that private power stations and small hydraulic power stations demand high reliability also, but they also demand economy and controller space saving as power plants in parallel with this.

(1) Integrated control function type digital controller

Integrated control function type systems which perform all control with one PC are being applied in the small power station field. For example, with the system shown in *Fig. 2*, the cost and installation space of the controllers can be reduced substantially by implementing main unit control, AVR, and governor with one PC.

It is important that the PC for realizing an integrated control function type digital controller.

(a) have a memory capacity and processing speed capable of executing all functions.

(b) have software that can manage each control function independently.

(2) Remote I/O

Integrating the control functions eliminates the need for interface between devices and reduces the input/output devices can be reduced substantially.

The control cables can also be reduced considerably by distributing the I/O devices near each device and connecting the I/O devices and PC with a serial transmission line. The remote I/O composition is the functions necessary from the standpoint of promotion of digitalization of the auxiliary equipment in the future also.

2.2.2 Remote control system

Most hydraulic power stations are operated automatically by remote control and an operator is usually not stationed at the power station. Formerly, separate telecontrol equipment was installed in the power station, but the incorporation in a PC with the functions of telecontrol equipment is necessary because an integrated control function system is intended. Embodiment of remote maintenance functions which complete the inspection function is also expected.

2.3 Expansion of digitalization range

Digitalization in the power station control field has progressed up AVR and other functions which require high speed processing and most main functions are in the direction of digitalization. The items which advance digitalization are integration with I/O card and interface converter and the peripheral control relationship auxiliary equipment control, etc. Converter integration required high speed processing of AC waveform analysis operation, equipping of function PIO with the same functions built in, etc.

Digitalization of auxiliary equipment control and other single function parts with many input/output channels has is lagging from the standpoint of cost merit, but the use of general-purpose small PC, application of remote I/O, and other digitalization is being promoted.

3. APPLICATION PC FUNCTIONS

The functions of the PC making up a power station control system and the characteristic items regarding its composition are described below.

3.1 Redundancy

Fig. 3 Redundancy system configurations

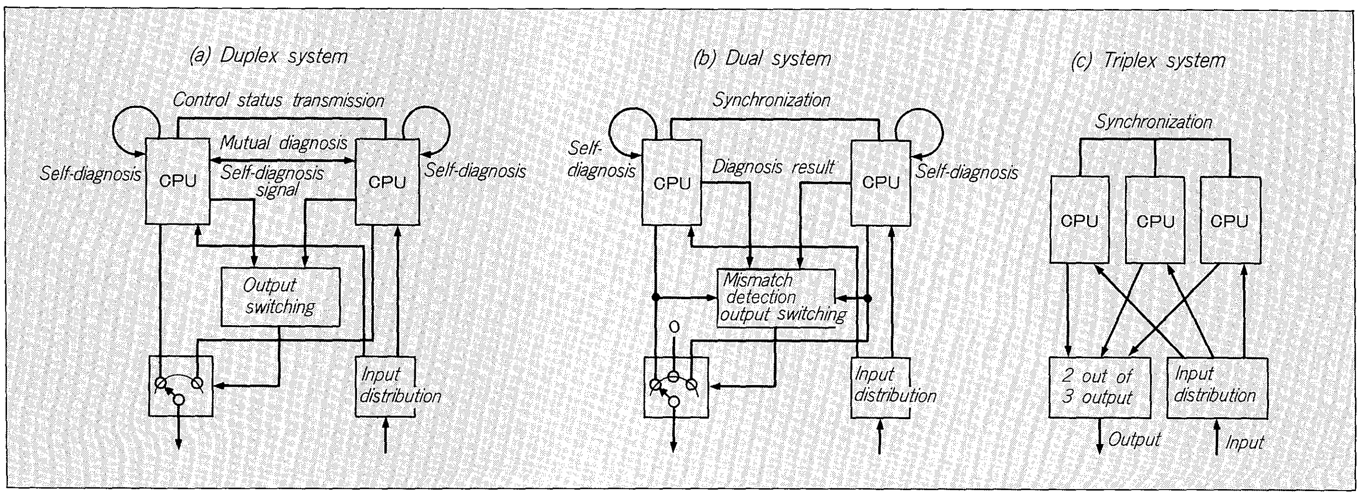


Table 1 PC basic specifications example

Item		Contents
Instruction word	Kinds	112 kinds
	Speed	Sequence instruction: 0.2 μs Arithmetic instruction: 0.5 μs Analog operation: 2 ~ 10 μs
Number of programs		Cyclic operation: 64 Periodic interrupt program: 32 External interrupt program: 16
Memory	Program	128k words
	Data memory	64k words

Table 2 PC instruction word examples

Classification	Description
Sequence	• AND, OR, INVERSE • SET, RESET
Arithmetic	• Fixed point • Floating point
Function	• Square root • Trigonometrical function • Exponential function
Analog operation	• Differentiation, integration • Primary lag • Limiter relation
Others	• Matrix function

The methods of minimizing the affects of the fault and continuing operation if a fault should occur are fault masking which masks the fault point by duplexing and fall back which disconnects the faulty part and continues operation with the healthy parts. The concrete fault masking method is redundancy. For a PC, the central processing unit (CPU) is generally made redundant. For CPU redundancy, there is the duplex system, dual system, and triplex system shown in *Fig. 3*. For CPU multiplexing, data synchronization between CPU, control status and data continuation at fault and other functions are necessary. Incorporation of these functions as basic PC functions is desirable. Since the application program must also be aware of these functions, the internal construction must be clarified.

Especially important I/O are also made redundant. For input duplexing, a data comparison detection function is provided inside the PC. However, output deplexing requires an external data comparison and detection selection circuit.

PC redundancy also enhances duplexing of network, remote I/O line, and other signal transmission systems, besides the CPU and I/O parts.

3.2 Speeding up and advanced functions

To realize AVR, GOV, etc. for power station control, filter, PID, and other analog operations, trigonometrical function to handle AC waveforms, etc. and a processing speed with an operation period of about 3 to 5 ms must be realized. For an integrated control function type system, installation of multiple independent programs is also necessary. Therefore, PC functions are:

(1) high instruction execution speed,

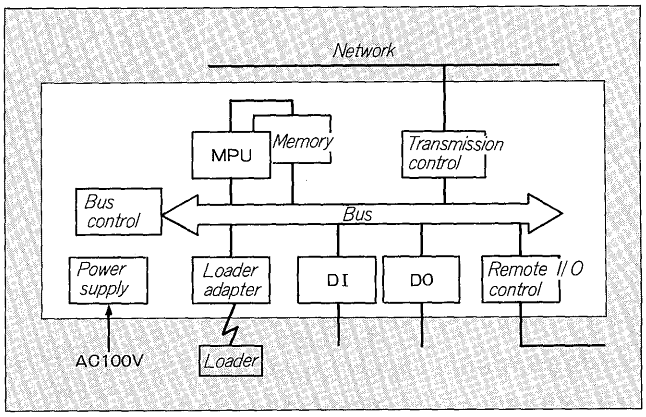
(2) analog operation, trigonometrical function, and other convenient instructions for power plant control,

(3) management and execution of multiple programs and execution of accurate periodic interrupt programs,

(4) ample program memory capacity.

PC specifications and instruction word examples are given in *Tables 1 and 2.*

Fig. 4 Digital controller configuration



3.3 Network interface

Private network between CPUs, telecontroller, remote I/O and many other types of interfaces are necessary. These functions operate as option functions.

To realize these option functions, the PC defines a common bus and stacks function modules on this bus in building block form. (See *Fig. 4.*) The network interface function module itself is intelligent and performs transmission protocol control and data management.

3.4 I/O part menu

The basic functions of a PC are decided by the CPU, but for concrete operation, the menu of the I/O part is important. Besides the standard PIO, the following are effective as a power station control PC:

(1) Turning speed counter module

A pulse generator is installed to the generator shaft and the speed is detected from the pulse input.

(2) High reliability analog output module

This module duplex outputs the especially important analog outputs (governor valve opening command, etc.). The self-diagnosis function is strengthened and a function which switches to the opposite side automatically at a self-alarm is provided.

(3) AC signal input module

This module receives the AC input directly instead of via a converter and analyses its waveform. It contains a signal processor and extracts the voltage and current effective value, active and reactive power, power factor, etc.

4. FUTURE TREND

Current PCs have most of the functions necessary for use in power station control. Their future trend is discussed below.

First, is harmonization with the protection relay system. The PC is being speeded up and AVR and automatic synchronization is being incorporated into the maintenance range. Concrete studies will have to be started because the PC is steadily approaching a protection system from the standpoints of construction and function, the increase in the trend toward introduction of preventive maintenance and similar management systems, the appearance of the demand for interface unification for data management one-dimensionalization at normal operation, etc.

The second is upgrading of maintenance functions. The self-diagnosis function of the PC, which is the controller, and the plant diagnosis function are advancing, but it is felt that the introduction of AI technology and full scale practicalization of remote maintenance will progress rapidly.

Full scale introduction of CRT operation, commercialization and development of small PC, construction of a superior cost-performance reduncy system, etc. is expected to advance.

5. CONCLUSION

The digital controller for power station was outlined above from the standpoint of PC application. Fuji Electric offers safer power station control systems while planning the introduction of a preventive maintenance technology architecture and other newest technology based on its abuncant record of achievements in digitalization of large hydraulic power stations and its large thermal power digital control experience of the 1980s.